Q330 Timing

IRIS PASSCAL Instrument Center

This document describes how the Quanterra 330 digital acquisition system

- keeps internal time,
- synchronizes internal time with a GPS clock,
- time stamps data,
- reports differences between internal and external time, and
- reports timing quality information.

It also describes how the Baler, Socorro and Antelope time stamp data and handle phase errors and timing quality information.

Internal Timing

The Q330 keeps time internally using a Temperature Compensated Voltage Controlled Crystal Oscillator (TCVCXO) with a nominal drift rate of 0.1ppm (< 1 millisecond per day). When the Q330 powers up, the initial date and time is based on a time of day clock and is updated according to the oscillator thereafter. The time of day clock, which runs on internal batteries, maintains the date and time while Q330 power is off. Its batteries last about seven years.

External Timing

The Q330 contains a GPS engine (a Motorola M12) and an external antenna. By default, the GPS engine is configured to power down 3 hrs between obtaining satellite locks. It will stay powered until the oscillator is adjusted such that the phase difference between a GPS 1 Hz pulse and a 1 Hz pulse inside the Q330 have a phase error of < 5 μsec for 1 minute or until the GPS has been powered longer than a configurable maximum time limit (2 hours by default). Since the amount of time that the GPS engine remains powered depends on the length of time needed to adjust the TCVXCO, the time at which the GPS engine powers up varies as well. An exception to this is that the GPS engine will power up every 24 hours at a specified time to avoid precession of power cycling. Alternatively, the GPS can be powered continuously, powered only until a satellite lock is obtained, or powered for a set period of time.

A typical timing cycle consists of the GPS clock obtaining a 3D satellite lock and returning UTC time. The Q330 compares the new UTC time with its internal clock time to determine the current phase error. The Q330 also adjusts its TCVCXO oscillation rate to decrease the difference between the GPS and internal clocks. Once the phase error has been reduced to within 5 μsec, the clocks have a phase locked loop. The Q330 adjusts the TCVCXO oscillation rate so that the phase error remains within 5 μsec for one minute before powering the GPS clock down. The Q330 retains the last measured phase error before switching the GPS engine off and applies this constant time correction to all data records acquired while the clock is unlocked. It also holds the TCVCXO rate at the rate obtained during the phase locked loop.

If the phase error exceeds the "resync threshold" programmed in the Q330 configuration (50 milliseconds is the default), the Q330 will interrupt sampling in order to resynchronize sampling with the GPS clock. This is a rare occurrence and usually indicates that reception is too poor to maintain phase lock loop tracking. If this occurs, network operators should recheck whether the equipment is working or whether the antenna should be moved.

Time Stamps

Q330: The Q330 packages data into 1 second data records and sends them to a Data Processor (DP) for repackaging into miniSEED. Each data record, which is broken up into multiple fragments if it will not fit into a single QDP packet, includes a data record header with a sequence number that begins at zero when the Q330 is powered and increments each second. Each data record includes a "channel" that reports

- seconds offset since January 1, 2000 for the latest power up
- microsecond offset from the current second (a number from 0 to 999999)

A DP queries the Q330 for the FIR filter delays for each data stream and constructs the start time of the data records as follows:

$$time = data\ record\ sequence\ number + seconds\ offset + (\mu sec\ offset / 10^6) - FIR\ delay$$

This time is in floating point seconds since January 1, 2000 and must be converted into a date-time format by the DP before being written to the miniSEED header.

Time stamps for most miniSEED records require interpolation, since the beginning of a miniSEED record rarely coincides with the beginning of a data record and one miniSEED record usually spans several seconds. How this is handled depends on the DP.

Baler and Socorro: These DPs base time stamps and timing quality for miniSEED records on the timestamp of the 1-second data record with the best clock quality that falls within the duration of the miniSEED record. They extrapolate the time back to the beginning of the miniSEED record based on the number of samples that precede this time stamp and the nominal sample rate.

Antelope Real-time: Antelope's ***orb2db*** program constructs miniSEED records and time tags them with respect to the beginning of a continuous data segment. At startup or after a time tear, the beginning of a 1-second Q330 data record, a miniSEED record and a wfdisc entry will all coincide and have the same time stamp. Time stamps for subsequent miniSEED records are calculated from this initial segment's start time, the number of samples and the sample rate. ***orb2db*** will use the nominal sample rate from the Q330 data record for this calculation if it is in agreement with the 1-second data record time stamps. Otherwise it uses a sample rate calculated from the number of samples and time stamps in the Q330 1-second data records. ***orb2db*** stores this calculated sample rate in the miniSEED header as Blockette 100.

Phase Error Reporting

Baler and Socorro: These DPs report the *phase error* – the difference between the GPS and internal clock while the GPS is locked – as the LCE state of health channel. Between

GPS locks this channel reports the last measured phase error. The conversion factor for the LCE channel is 1 count per percent and its sample rate is 1 Hz.

The Baler LOG channel also reports the *phase error difference* – the difference between the newly measured phase error during a lock and the last phase error measured from the previous lock (the HOLD value). These differences are reported as a "jump" if it is less than the "resync threshold" and as a "JUMP" if it is larger. A "JUMP" can be several seconds in size; it is not limited in size to a single phase length.

Antelope Real-time: This DP displays the most recent phase error measurement as a status parameter in the program ***dlmon***.

Clock Quality Reporting

Q330: In each 1-second data record, the Q330 also sends

- a clock status bitmap
- the minutes since GPS lock was lost, and
- the clock phase loop status.

It also will send

- the adjustment made to the TCVCXO in counts

every 10 seconds and

- GPS status
- reason for GPS cold start (when applicable)

as needed or requested. How this raw information is handled depends on the DP.

Baler and Socorro: These DPs will construct the following SEED-style timing quality indicator using the clock status bitmap and time since lock was lost plus the Clock Logging parameters from the DP token:

100% - clock is LOCKED: it has a phase locked loop and its phase error is less < 5 μsec,
90% - clock is TRACKING: the GPS clock has a 3D fix on the satellites and the Q330 is adjusting its internal clock rate to reduce the phase error,
80% - the GPS engine has just powered on and is receiving time from the satellites,
10-60% - HOLD: the GPS is off and the phase error at the time of last unlock is held; its correction is applied to the data record headers until the next lock. Clock quality decreases by 1% for every 10 minutes that the GPS is unlocked to a minimum of 10%.
0% - the GPS clock has not locked since the Q330 powered up.

A value of 80% or higher indicates that there is an external time reference present. The value drops immediately to 60% when the GPS engine powers down. The value will not fall below 10% unless the Q330 reboots.

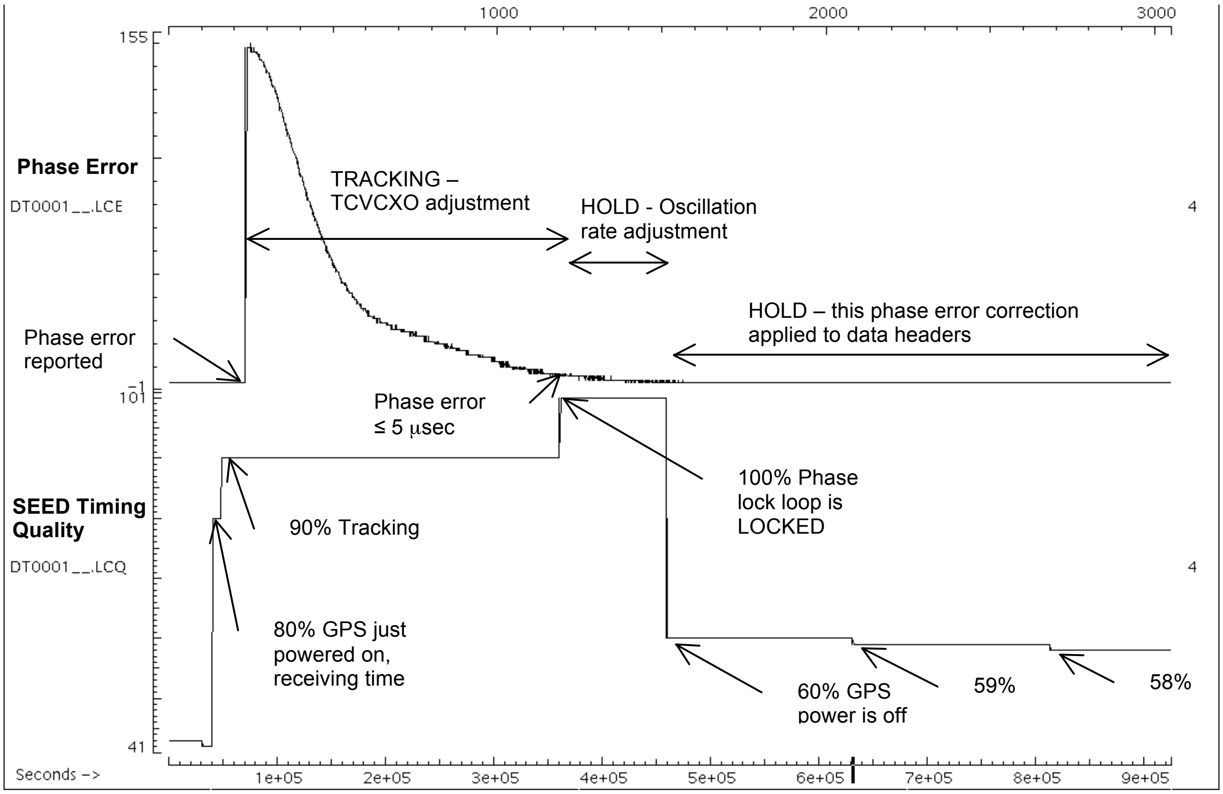

Figure 1. Q330 timing as illustrated by the Baler LCE (phase error) and LCQ (timing quality) channels.

These DPs report the SEED clock quality in blockette 1001 of the miniSEED headers and (optionally) digitized as a miniSEED channel (LCQ by default). The conversion factor is 1 count per percent and the sample rate is 1 Hz.

MiniSEED channels reporting the number of minutes since lock was lost (LCL) and the oscillator adjustment value (VCO in counts) are also available. The ACE channel, which is not a time series, describes selected status parameters for the TCVCXO and GPS when changes occur and on a regular basis as configured in the Q330.

<u>*Antelope Real-time:*</u> The Antelope DP makes the following regularly sampled raw timing information available as optional miniSEED channels:

- TCVCXO adjustment in counts (channel data_vco or QVC by default),
- clock status bitmap (data_clk_qual or QCQ),
- GPS Phase lock loop status: 0 = not enabled, 1 = HOLD, 2 = TRACKING, 3 = LOCKED (data_clk_pll or QPL), and
- Time since lock was lost in seconds (data_clk_ltc or QCL).

Antelope also preserves the GPS status and reason for cold start, but since these are reported only as needed, they are not available as miniSEED channels. Antelope does not calculate a SEED-style timing quality percentage as it does not use DP tokens nor does it write a blockette 1001 to the miniSEED headers.

A Note on Non-real-time Data Processed Using Antelope

When Antelope is not serving as a DP but is packaging data from stand-alone stations into miniSEED day volumes, it preserves the time stamps and timing quality information already in the data.

Aknowlegements

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